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TNO report

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The influence of protection, mobility and risk perception on the behaviour and physical performance of a combat soldier

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De invloed van bescherming, mobiliteit en risicoperceptie op het gedrag en de fysieke prestatie van een gevechtssoldaat

Probleemstelling

De invloed van ballistische bescherming op de fysieke prestatie van de gevechtssoldaat is in het verleden meerdere malen onderzocht. Inzicht in risicoperceptie bij een bepaalde mate van bescherming en de invloed daarvan op het gedrag en de prestatie van de gevechtssoldaat onder operationele bedreigende omstandigheden ontbreekt.

In het kader van het programma Soldaateffectiviteit (V205) is in 2005 een experimentele veldstudie gestart om inzicht te krijgen in de invloed van ballistische bescherming, mobiliteit (gewicht, bescherming, bedekking) en risicoperceptie op gedrag en de fysieke prestatie. Uit deze studie bleek dat de mate van bescherming in combinatie met de dreiging resulteerde in minimale variaties in risicoperceptie en als gevolg in minimale veranderingen in gedrag. De bekendheid van de gevechtssoldaat met de aangeboden dreiging, alsmede de opzet van de test, verklaarden voor een groot deel de minimale variaties in risicoperceptie en gedrag. Op basis van de verkregen inzichten uit het veldexperiment in 2005 is besloten een vervolg veldexperiment in 2006 uit te voeren

Beschrijving van de werkzaamheden

28 gevechtssoldaten, onderverdeeld in 14 buddyparen, namen deel aan het 2006-veldexperiment in Oostdorp. De buddyparen voerden met verschillende beschermende condities een Fire & Manoeuvre actie uit over een afstand van 60 meter. De buddyparen werden tijdens de actie beschoten met Simunition om een realistische dreiging te verkrijgen en aldus risicoperceptie te bewerkstelligen. Om inzicht te krijgen in het gedrag en de fysieke prestatie werd voor en na de actie gevraagd hoe inspannend, bedreigend en spannend de actie werd ervaren. Tijdens de actie werden het aantal keren liggen, de benodigde tijd, de schietprestatie, het aantal treffers op het (on)beschermde lichaam en de hartslag gemeten.

Resultaten en conclusies

Onbeschermd voelden de buddyparen zich voor de actie meer bedreigd dan beschermd. Dit gaf aan dat de gevechtssoldaten zich bewust waren van de bedreigende situatie en de mate van bescherming. Ondanks het feit dat ze zich bewust waren van de bedreiging en de mate van bescherming, gingen de buddyparen niet vaker in dekking en was er geen verschil in de benodigde tijd om de afstand af te leggen. Er werd dus geen ander gedrag vertoond tijdens de onbeschermde condities vergeleken met beschermende condities.

We kunnen dus concluderen dat risicoperceptie in dit experiment geen invloed heeft gehad op strategie.

Toepasbaarheid

In deze studie is aangetoond dat het mogelijk is een bedreigende situatie op te stellen, waarin proefpersonen zich afhankelijk van de mate van bescherming wel of niet bedreigd voelen. Hiermee komen we steeds dichter bij de realiteit. Op grond van de bevinding dat in dit experiment, met beperkte keuzemogelijkheden om in dekking te gaan, risicoperceptie niet de strategie doet veranderen, kunnen computermodellen, die operationele prestaties voorspellen, worden geoptimaliseerd. We bevelen aan ook vergelijkbare experimenten te verrichten met meer keuzemogelijkheden om in dekking te gaan, waarbij we wel verschillen in gedrag en fysieke prestatie verwachten.

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Samenvatting

Inleiding
Hoewel de invloed van ballistische bescherming op de fysieke prestatie veelvuldig is onderzocht, is er beperkte informatie over risicoperceptie van een gevechtssoldaat bij een bepaalde mate van bescherming en de invloed daarvan op gedrag tijdens bedreigende situaties. Op basis van de 'lessons-learned' uit de studie van Koerhuis & Verhagen (2005), is de Fire & Manoeuvre actie geoptimaliseerd met als doel de invloed van ballistische bescherming, mobiliteit (gewicht, bescherming, bedekking) en risicoperceptie op gedrag en de fysieke prestatie in kaart te brengen.

Methode
28 gevechtssoldaten, onderverdeeld in 14 buddy paren, namen deel aan de studie. De gevechtssoldaten hadden geen ervaring met Simunition. De buddy paren voerden een Fire & Manoeuvre actie uit over een afstand van 60 meter onder verschillende beschermende omstandigheden (onbeschermd, onbeschermd met loodgordel, ballistisch vest, Simunition pak, Simunition pak met loodgordel). Simunition werd gebruikt om risico perceptie in te voeren. Voor en na de Fire & Manoeuvre actie werd gevraagd hoe inspannend, bedreigend en spannend de actie werd ervaren. Tijdens de actie werden het aantal keren liggen, de benodigde tijd voor de actie, de schietprestatie, het aantal geïncasseerde schoten op het lichaam (op beschermde en onbeschermde delen van het lichaam) en hartslag gemeten om het gedrag en de fysieke prestatie in kaart te brengen.

Resultaten
Voor de Fire & Manoeuvre actie werd bij de onbeschermde condities de bedreiging als significant hoger ervaren, waaruit blijkt dat met Simunition een bedreigende situatie te creëren is. Desondanks werden er geen verschillen gevonden in het aantal keren liggen en de benodigde tijd voor de actie tussen de verschillende condities. De meeste treffers op het lichaam (op beschermde en onbeschermde delen) werden geïncasseerd tijdens het dragen van het ballistisch vest (gemiddelde 2,6 schoten). Van het totaal aantal treffers werden bij de onbeschermde conditie zonder loodgordel de meeste treffers door onbeschermde delen van het lichaam geïncasseerd (1,4 treffers (66,7% van het totaal aantal treffers). De gemiddelde hartslag tijdens het dragen van het Simunition pak zonder of met loodgordel (133,6 and 133,4 beats/minute respectievelijk) was significant hoger dan bij de onbeschermde conditie (126,8 beats/minute). De maximale hartslag was niet significant verschillend tussen de condities.

Conclusies
De significant hoger ervaren bedreiging voor de actie bij de onbeschermde condities toonde aan dat de gevechtssoldaten zich bewust waren van de bedreigende situatie en de mate van bescherming. Tijdens de actie hadden proefpersonen (buddy paar) en vijanden beide de mogelijkheid om te schieten en in dekking te gaan. Ondanks het bewust zijn van de bedreiging en de mate van bescherming, vertoonden de proefpersonen geen ander gedrag tijdens de onbeschermde condities vergeleken met beschermende condities. Verwacht wordt dat een toename van het aantal keuzemogelijkheden tijdens de Fire & Manoeuvre actie (meer mogelijkheden om in dekking te gaan over een langere Fire & Manoeuvre afstand) zou kunnen resulteren in grotere verschillen in gedrag en fysieke prestatie voor de verschillende condities.

Summary

Introduction
Although the influence of ballistic protection on physical performance has frequently been studied, the effect of the soldier's confidence in his ballistic protection and the influence on his behaviour during threatening situations is still unresolved. Based on the lessons-learned from the first experiment (Koerhuis & Verhagen, 2005) a modified, more realistic Fire & Manoeuvre action was performed to assess the overall effect of ballistic protection, mobility (weight, protection, surface) and risk perception on behaviour and physical performance of the individual combat soldier.

Methods
Twenty-eight combat soldiers, divided in 14 buddy pairs, participated in this study. The combat soldiers were unfamiliar with Simunition. The buddy pairs performed a Fire & Manoeuvre action over a distance of 60 meter wearing different protection conditions (unprotected, unprotected with hip belt, ballistic vest, Simunition suit, Simunition suit with hip belt). Risk perception was introduced using Simunition. Scores on perceived threat, anxiety and exertion were asked prior and after the Fire & Manoeuvre action. During the action, behaviour and physical performance was assessed by measuring the number of times lying on the ground, the time necessary to cover the distance, shooting performance, the number of hits on the body (protected and unprotected) and heart rate.

Results
Prior to the Fire & Manoeuvre action a significantly higher threat score was found wearing the unprotected conditions, illustrating the risk perception using Simunition. Despite these higher threat scores, no significant differences were found in the number of times lying on the ground and the time to cover the distance. The highest number of hits on the total body (protected and unprotected parts of the body) was found wearing the ballistic vest (2.6 hits on average). Of the total number of hits on the body, the highest number of hits on the unprotected body was found wearing the unprotected conditions without hip belt (1.4 hits (66.7% of the total hits)). The mean heart rate was significantly higher wearing the Simunition suit without or with hip belt (133.6 and 133.4 beats/minute respectively) compared with the condition wearing the combat suit (126.8 beats/minute). No significant difference in maximal heart rate was found for the different protection conditions.

Conclusions
The significantly higher threat score before the action wearing the unprotected conditions indicated that the combat soldiers were aware of the situation and the amount of protection they weared. During the action an equal fight was observed between subjects and enemies, with both options to fire and to hide.
Despite the awareness of the situation and the amount of protection, the subjects did not behave differently wearing the unprotected conditions compared with protected condition. It is expected that more alternatives during the Fire & Manoeuvre action (more options to hide over a longer Fire & Manoeuvre distance) may yield a difference in behaviour and physical performance for the different protection conditions.

Contents

1 Introduction

1.1 Context

Part of the modernisation of the equipment of the Dutch combat soldier, the Dutch Dismounted Soldier System, includes adaptation of the protection level in order to meet the increased protective demands. The ballistic protection level of the soldier needs to be suited for the operational context and task. During peace operations, the protection level has to be sufficient for the situation without deterring the civilian population. High intensity scenarios may require the highest level of protection.
A higher protection level may have a negative effect on physical performance due to its weight. Daanen & Koerhuis (2003) already concluded that increased weight and thermal load due to wearing protective clothing does influence physical performance in a negative way. Holewijn & Lotens (1987) observed a 1% physical performance reduction at an increase in weight of 1 kg. Apart from the weight, also the location of the protective clothing is relevant. Further from the centre of mass of the body the energy cost of carrying weight is increased (Soule and Goldman, 1977; Miller and Stamford, 1987). Although on the one hand more protection can result in a higher protection level, the decrease in physical performance due to weight and location of the weight can on the other hand influence this protection level in a negative way. Therefore a thorough evaluation of the balance between protection and function under conditions of threat is necessary.
Ashbey et al. (2004) studied the influence of six different protective suits, varying in weight and protection level, on physical performance during five functional tests. However, no threat was simulated during the experiments. The balance between protection level, weight and performance was predicted with computer simulations, based upon the increased physical load and decreased mobility of protective clothing. In theoretical studies so far, an optimal combination between protection level, load and performance was based on the increased physical load and decreased mobility of protective clothing only.
There is a lack of information about the influence of the amount of protection in combination with a realistic threat has on physical performance and behaviour. Reports have been found in which threat consisted of environmental stress (cold) and psychological pressure (Liebermann et al., 2002). However, no reports were found in which threat was related to the possibility of being shot.
In a realistic military operational confrontation (with the possibility of being shot), it is expected that, apart from the protection and weight of protective clothing, also risk perception of soldiers as well as behaviour influences the overall performance of the soldier. Ballistic protection can influence the behaviour of the combat soldier mentally (risk perception). The influence of risk perception may become apparent in different ways: acceleration, deceleration, task performance quality, change in task performance etc and can therefore, apart from increased load, also be of influence on combat readiness as well as survivability and sustainability of the soldier.

1.2 The 2005 experiment

Within the framework of the National Soldier Modernisation Programme, an experimental study was started focussing on the overall effect of ballistic protection, mobility (weight, protection, surface) and risk perception on behaviour and physical

performance of the individual combat soldier (Koerhuis & Verhagen, 2005, Appendix I). A typical military 'fire-and-manoeuvre' action was carried out by well-trained soldiers. Various ballistic protection levels were used.
It was generally agreed upon that the most realistic experimental simulation of the possibility of being shot at, which is feasible and ethically justified, is related to a pain sensation on unprotected body regions. In this study Simunition was used for the pain sensation. It is expected that in order to avoid this pain sensation (the soldiers' risk perception) the soldiers' behaviour will change. Not with standing the effort and experts opinion involved during the design process only minimal differences in behaviour were observed.

From a critical re-examination of the results found in combination with the set-up of the experimental program it became apparent that the results so far were mainly due to reasons unforeseen during the definition and preparation of the experimental program and/or due to national regulations concerning test persons in combination with Simunition, amongst others the following points are mentioned.

- The threatening situation during the experiment appeared to be too limited to emphasize the desired effect: The test subjects (special forces) were already familiar with the effect of Simunition. Due to the changed regulations nowadays also soldiers unfamiliar with simunition are allowed to be exposed to simunition.
- The military test persons should be familiar with the military actions included in the experimental program. For the special forces involved in the 2005 experiments, fire & manoeuvre is not included in their daily program.
- The test environment did not offer adequate, realistic coverage opportunities for the test subjects as required for a fire & manoeuvre action.
- Test subjects and the 'enemies' shooting with simunition knew each other. As a consequence animosity and/or rivalry between persons and/or groups might in some cases obscure the 'enemy' shooting instructions and divert from the objective of the experiment.

For all parties involved it was evident that experiments are required to increase the understanding and assessment of the influence of protection, mobility and risk perception on behaviour and physical performance of a combat soldier. Based on the lessons-learned from the 2005 experiment it was suggested that adaptations of the design of the experiment in combination with the selection of the test subjects will improve the overall results considerably.

1.3 The 2006 experiment

Limited cover options and familiarity with Simunition were the most important explanations for the minimal variation in risk perceptions for the 2005 experiments. Based on these explanations, the study was modified and repeated with well trained soldiers, unfamiliar with Simunition and familiar with the military actions included. More realistic coverage opportunities were offered to the test subjects. Furthermore, the test subjects were allowed to fire with Simunition at the enemy in contrary to the 2005 experiment, in which test subjects were only allowed to fire at rising dolls.

2 Method

The protocol consisted of a modified version of the Fire & Manoeuvre action in the 2005 experiment of Koerhuis & Verhagen (2005). The 2006 protocol was worked out in close cooperation with military experts, focussed on mimicking a realistic Fire & Manouevre action. Amongst others the following modifications should be highlighted.

- More defending positions in the field, offering protection for the lying person (2005 experiment: protection only offered by terrain).
- The 'enemy' was pinpointed in two (lying) static positions in the field (2005 experiment: walking around).
- The buddy teams were allowed to shoot their 'enemies' (2005 experiment: shooting at mock-ups, thus no suppression or reaction of the enemy).
- The 'enemy' was played by the military instructors, thus avoiding animosity and rivalry (2005 experiment: combat soldiers).

Because the influence of the weight and mobility of the clothing conditions on performance was already assessed in the pre- and post test of the study of Koerhuis & Verhagen (2005), the pre- and post test were excluded in this study.

2.1 Subjects

Twenty-eight healthy combat soldiers (age: 21.4 years ± 1.9) participated in this study. All were physically highly trained, had no physical complaints prior to the study and were unfamiliar with Simunition. The twenty-eight combat soldiers were divided in fourteen already existing buddy pairs. Each Fire & manoeuvre action was performed with one buddy pair. The buddy pairs remained the same during the entire study.

2.2 Simunition

Simunition is used to create a threatening situation. It is expected that the behaviour of the soldier will change in order to avoid the pain sensation (the soldiers' risk perception) which will be inflicted by a simunition hit on the unprotected body. A hit on the unprotected subjects' body may result in damage (haemorhage) on the skin (see Figure 1). Simunition was preferred because of the pain sensation in contrast to Simlas, which is comparable to the Miles system.

Figure 1 The effect of a Simunition impact on the arm.

2.3 Protection Conditions

To simulate the effect of ballistic protection and mobility (weight, protection, surface) attention was paid to the 'protection' conditions. Risk perception was related to the total protected body coverage. As a result, it was decided to define the protection conditions to enable comparisons between '*no protection ~ high risk perception*' – '*partial protection ~ medium risk perception*' – '*total protection ~ no risk perception*' – with respect to the '*weight-surface distribution*' (Table 1, Figure 2):

- condition A and B are currently in service;
- the simunition suit (condition C and D) offers total protection againts simunition impacts. The protection level of the simunition suit simulates the ultimate ballistic protection dream;
- the belt around the hips (condition D and E) is used to add an addition weight burden to the subject without improving the protection level.

Table 1 Protection conditions.

Protection Condition		Weight (kg)	Body Coverage (%)	Protection	Risk perception
A	- combat suit	0	0	unprotected	High
B	- combat suit - ballistic vest	10.9	33.3	partially protected	Medium
C	- combat suit - simunition suit	2.1	75	protected	Low
D	- combat suit - simunition suit - belt around hips	2.1 + 8.8	75	protected	Low
E	- combat suit - belt around hips	0 +10.9	0	unprotected	High

For safety reasons, the head and the hands were protected during all protection conditions. Body coverage is thus related to body minus head and hands.

Figure 2 Different protection conditions.

2.4 Fire & Manoeuvre test

In the modified Fire & Manoeuvre action a threatening situation was simulated. During this action the influence of the protection condition on the behaviour and physical performance was measured.
During the Fire & Manoeuvre action a rural terrain of ~60 meter was covered in buddy pairs. Their primary goal was to cover the distance unhurt; the second goal was to cover the distance as fast as possible. The action consisted of two parts: A-B and B-C (Figure 3, Table 2). Of each buddy pair, one combat soldier remained on the left side of the enemies and one combat soldier on the right side of the enemies. Of the enemies, the left enemy fired on the combat soldier on the left side and the right enemy fired on the combat soldier on the right side.

Table 2 Measurements during the Fire & Manoeuvre action.

Traject	Distance	Description	Measurement
A-B	~30 m	Fire & Manoeuvre	- Time (s) to cover the distance from A to B - Times lying down on the ground - Number of hits on enemies
B-C	~30 m	Fire & manoeuvre	- Time (s) to cover the distance from B to C - Times lying down on the ground - Number of hits on enemies
A-C	~60 m	Total distance	- Number of hits on subject's body - Heart rate

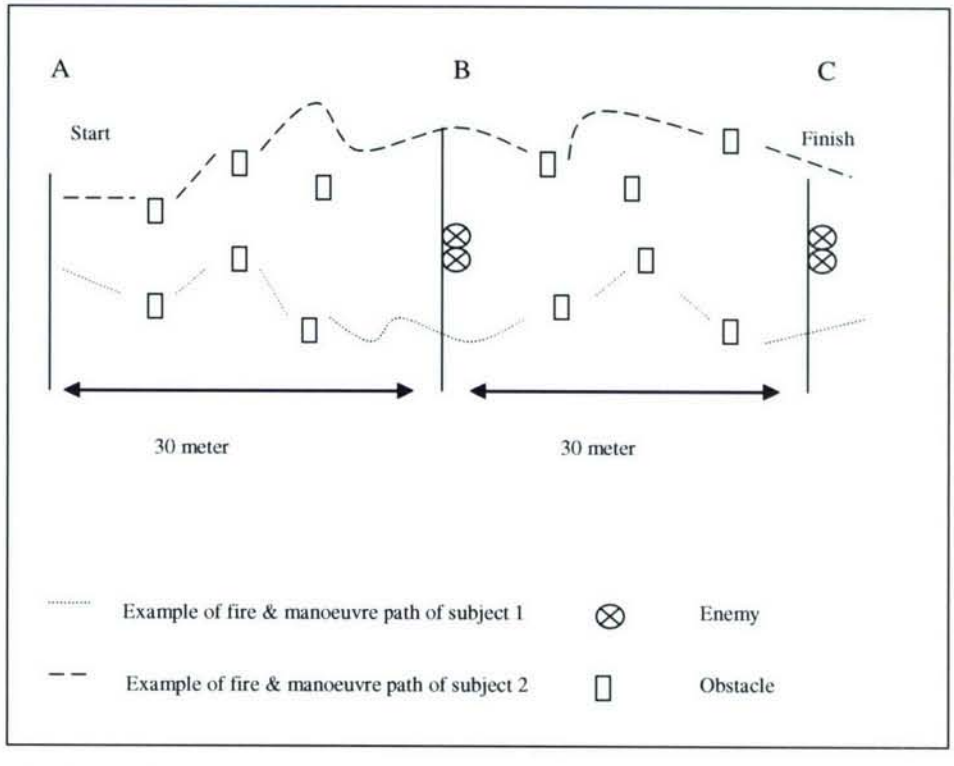

Figure 3 Fire & Manoeuvre action.

During the whole action (from A – C, 60 meter), the subjects were fired with Simunition (single shot mode). On the first 30 meter, the subjects were only fired by the enemies lying on 30 meter of the start. The enemies had 5 shots each. On the second 30 meter, the subjects were only fired by the enemies lying on 60 meter from the start. These enemies also had 5 shots each (Total number of shots on the whole 60 meter: 20 shots). The enemies lied on the ground behind obstacles. Firing at the subjects was only possible by exposing themselves to contra fire of the subjects, who had 15 shots each for the whole 60 meter. The time to cover the distance, heart rate, the number of times lying on the ground, the hits on the protected and unprotected part of the body of the subjects and shooting performance of the subject on the enemy were taken for analysis. Figure 4 shows some illustrations of the Fire & Manoeuvre action.

Figure 4 Illustrations of the Fire & Manoeuvre action.

2.5 Subjective rating scales

Before and after the Fire & Manoeuvre action the individual subject scores on three subjective rating scales were asked.

Threat scale: With the threat scale a score was given for the amount of threat during the action varying between 0 (no threat at all) and 20 (extreme threat). The score for the amount of threat is also dependent on the experienced threat by the subject in the past.

Anxiety thermometer: With the anxiety thermometer (Houtman & Bakker, 1989), the amount of anxiety was scored by drawing a line on a horizontal scale ranging from no anxiety to maximal anxiety. The distance between the start of the horizontal scale (no anxiety) to the line was taken for analysis.

Physical exertion scale: With physical exertion scale a score for perceived physical exertion ranging from 0 (no perceived physical exertion al all) to 20 (extreme physical exertion) was given (Borg, 1982).

2.6 Experimental protocol

The Fire & Manoeuvre action was repeated 5 times, each time with a randomly selected (different) protection condition (Table 1). The actions were divided over 3 test days (2 actions on day 1, 2 actions on day 2 and 1 action on day 3). During the actions, the buddy pairs remained the same.
The time between the experiments was more than 1 hour, by which the initial subject's physical condition could be regarded as 'physical recovered'.

2.7 Data analysis

An ANOVA for repeated measurements was used to analyze whether statistically significant differences were found in the number of hits on the protected and unprotected body, number of times lying down, time to cover the distance, fire accuracy and heart rate between the different protection conditions ($p<0.05$). ANOVA for repeated measurements was also used to analyze whether significant differences were found in subjective rating scales before and after the Fire & Manoeuvre action wearing different protection conditions. A Tukey post hoc analysis was used to determine which test conditions caused the significant effect.
Statistica (Statsoft, Benelux, version 6.1) was used for statistical analysis.

3 Results

Although the combat soldiers were measured individually, the performance on the Fire & Manoeuvre action was the result of two combat soldiers together (buddy pair). Most of the measurements were described for the combat soldiers individually and as a buddy pair. Heart rate measurements and subjective scales (physical exertion, threat and anxiety) were described for individuals solely.

3.1 Effect of protection conditions

3.1.1 Number of hits

The primary goal was to cover the distance unhurt. Of the 20 shots fired by the enemies, individually most of the total number of hits (on both the protected and unprotected parts of the body) were taken wearing the ballistic vest (condition B). Almost no difference was found in the total number of hits taken on the body, performing the action with the unprotected condition without and with hip belt (condition A and E) and the Simunition suit with hip belt (condition D). Only 1.7 hits were taken wearing the Simunition suit without hip belt (condition C).
Although most of the hits were taken on the ballistic vest (condition B), only 0.9 hits (34.6% of the total hits) were taken on the unprotected body. Most of the hits on the unprotected body were measured performing the Fire & Manoeuvre action with the unprotected condition without hip belt and the unprotected condition with hip belt (condition A and E). The lowest number of hits on the unprotected body were found wearing the simunition suit without and with hip belt (condition C or D).
Table 3 and Figure 5 show the number of total hits (on both protected and unprotected parts) and the number of hits on protected parts ands unprotected parts separately.

Table 3 Total number of hits (on both protected and unprotected parts) and the number of hits on protected parts ands unprotected parts separately.

	Protection condition				
	A	B	C	D	E
Total hits	2.1	2.6	1.7	2.1	2.2
Protected part	0.7	1.7	1.6	1.8	0.8
Unprotected part	1.4 (66.7%)	0.9 (34.6%)	0.1 (5.9%)	0.3 (14.3%)	1.4 (63.6%)

In Figure 6, the number of hits on the protected, unprotected and total body was shown for buddy pairs. For buddy pairs the same number of total hits was found compared with the individually measured number of hits, with the highest number of hits wearing the ballistic vest. Also the number of hits taken on unprotected parts of the body was comparable with the individual measurements, with the highest number of hits wearing the unprotected condition without and with hip belt.

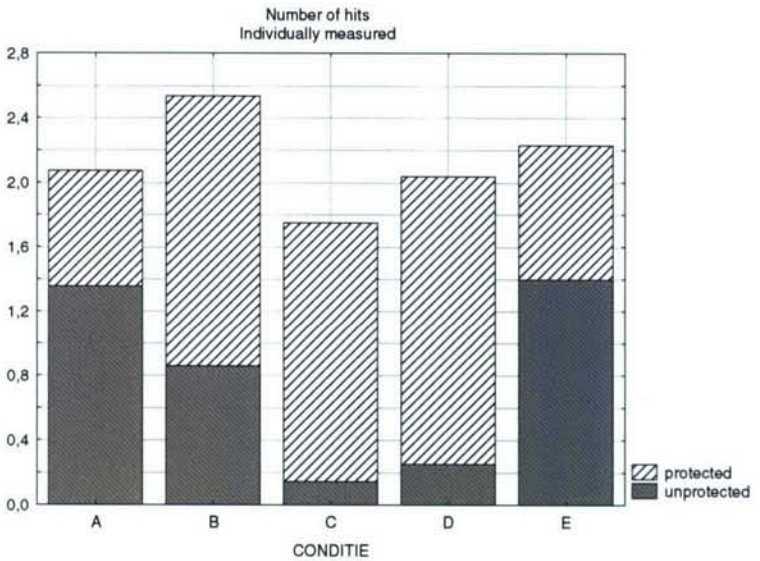

Figure 5 Individually measured total number of hits on protected and unprotected parts of the body.

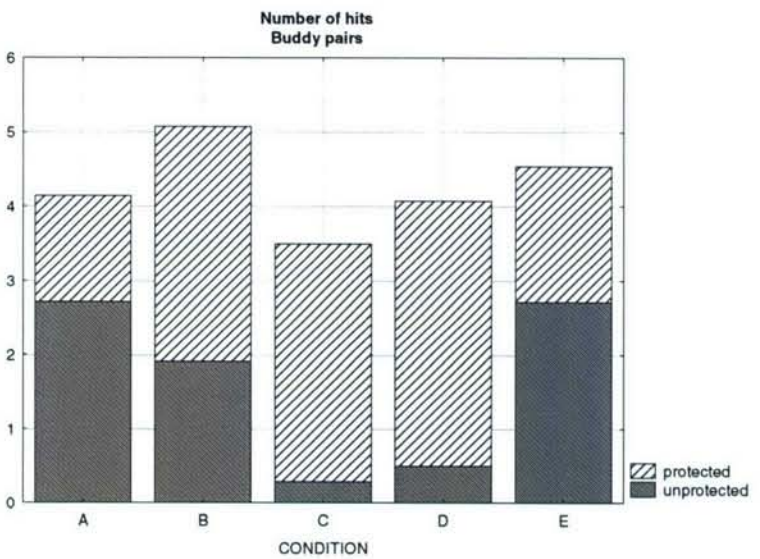

Figure 6 Total number of hits on protected and unprotected parts of the body for buddy pairs.

3.1.2 Lying down

No significant differences between protection conditions were found on individually measured number of times lying down on the ground on both the first and second 30 meter of the Fire & Manoeuvre action. Averaging the number of times lying down on the ground for buddy pairs was also not significantly different between conditions for both the first and second 30 meter. Only minimal difference was observed in the mean time lying on the ground with (maximal) protection (condition C) and almost unprotected (condition A) (61.0 and 62.3 seconds respectively).

3.1.3 *Time to cover distance*

The second goal of the Fire & Manoeuvre action was to cover the distance as fast as possible. The individual time and the average time for buddy pairs to cover the distance was not significantly different between the different protection conditions (Table 4).

Table 4 Time to cover distance (± standard error of the mean (SEM).

	Protection condition				
Individual time (s)	A	B	C	D	E
Trajectory 1	52.0	54.5	50.7	50.4	48.8
± SEM	2.7	3.6	3.0	2.6	2.1
Trajectory 2	83.8	87.7	82.6	82.3	79.0
± SEM	3.5	4.3	4.1	3.2	2.6
Buddy Time (s)					
Trajectory 1	51.0	54.0	50.7	51.2	49.6
± SEM	3.4	4.7	4.0	3.6	2.7
Trajectory 2	83.3	87.1	82.6	83.5	80.0
± SEM	4.6	6.0	5.7	5.1	3.4

3.1.4 *Heart rate (mean and maximal)*

Mean heart rate during the Fire & manoeuvre action was significantly different between the conditions (Figure 7, Table 5).

Table 5 Mean and maximal heart rate wearing the different protection conditions.

	Protection condition				
	A	B	C	D	E
Mean heart rate	126.8	132.3	133.6	133.4	131.3
(beats/min) ±SEM	2.7	2.2	2.0	2.0	2.7
Max. heart rate	167.6	169.5	169.7	170.9	168.4
(beats/min) ±SEM	2.0	2.1	1.6	1.9	2.9

The mean heart rate wearing the Simunition suit without or with hip belt (condition C and D) was significantly higher compared with the condition wearing the combat suit (condition A).

Although the highest maximal heart rate was found wearing a Simunition suit with hip belt (condition D), the maximal heart rate was not significantly higher compared with the other conditions (Table 5).

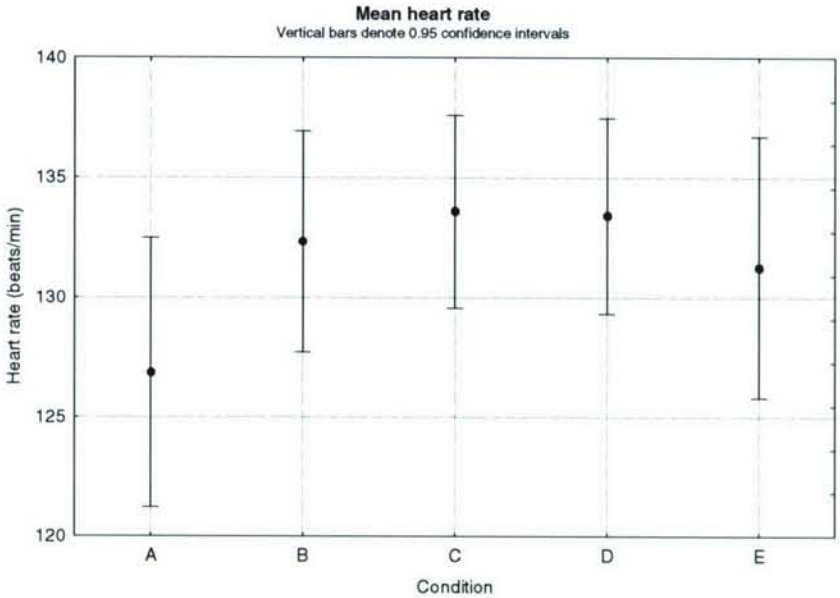

Figure 7 Mean heart rate wearing different protection conditions.

3.1.5 Fire accuracy

Besides protecting themselves for enemy fire, the buddy pairs could also fire at the enemies. Of the 15 available shots each (30 shots per buddy pair), on average less than 4 shots per buddy pair were not used, independent of the protection condition. Although over the first 30 meter the best shooting performance was observed wearing the combat suit with hip belt (condition E), the shooting performance was not significantly different over the first (trajectory 1: A-B) and second 30 meter (trajectory 2: B-C) wearing different protection conditions (Table 6).

Table 6 Fire accuracy.

	Protection condition				
Fire accuracy (#hits)	A	B	C	D	E
Trajectory 1: A-B	1.8	1.9	1.4	1.6	2.2
± SEM	0.4	0.5	0.3	0.3	0.5
Trajectory 2: B-C	0.3	0.3	0.4	0.4	0.3
± SEM	0.2	0.2	0.2	0.2	0.2

3.2 Subjective scales

3.2.1 Perceived Threat

Prior to the action, the scores on the threat scale were significantly different for the different protection conditions (Figure 8, Table 7). The threat score wearing the unprotected condition with hip belt (condition E), was significantly higher than the Simunition suit with and without hip belt (condition D and C) and the ballistic vest (condition B). A tendency was observed between the threat score wearing the unprotected condition A and both the ballistic vest (condition B) and the Simunition suit without hip belt (condition C). After the action, the threat score was not significantly different between the protection conditions.

For perceived threat, a significant difference was found in threat score prior to the action (mean score: 7.1) and threat score after the action, with a higher score after the action (mean score: 9.8) (Figure 8, Table 7).

Table 7 Perceived threat scores before and after the action.

	Protection condition				
Threat	A	B	C	D	E
Before action	7.6	6.6	6.6	6.8	8.0
± SEM	0.5	0.3	0.3	0.4	0.6
After action	10.4	9.5	9.4	9.8	9.6
± SEM	0.7	0.6	0.7	0.7	0.7

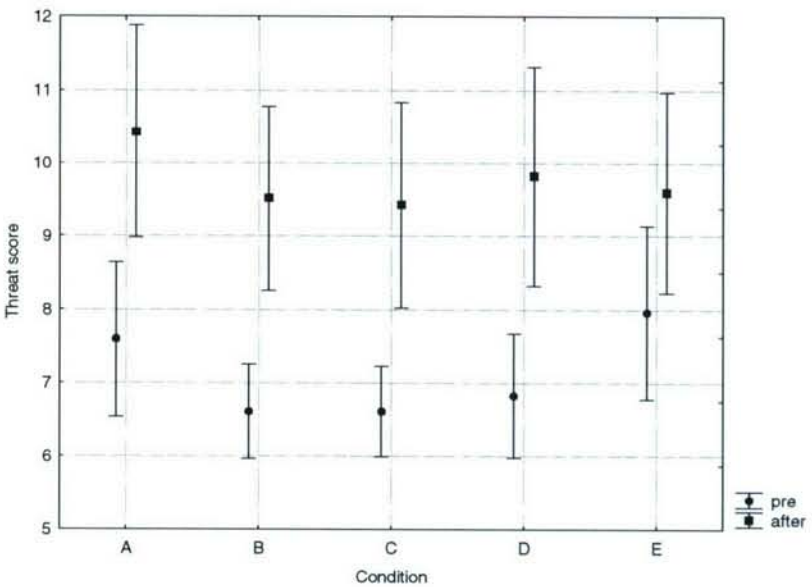

Figure 8 Threat scores prior and after the Fire & manoeuvre action for the different protection conditions.

3.2.2 *Perceived anxiety*

Prior to the action, the different protection conditions had no influence on the anxiety scores. Also after the action no influence of the different protection conditions was found (Figure 9, Table 8).

Table 8 Perceived anxiety scores before and after the action.

	Protection condition				
Anxiety	A	B	C	D	E
Before action	1.5	1.7	1.3	1.3	1.6
± SEM	0.4	0.4	0.3	0.3	0.4
After action	3.5	3.2	3.1	3.1	3.2
± SEM	0.5	0.5	0.5	0.5	0.5

Significant differences were found in mean anxiety scores prior to the action (mean score: 1.5) and after the action the action, with a higher score after the action (mean score: 3.2) (Figure 9).

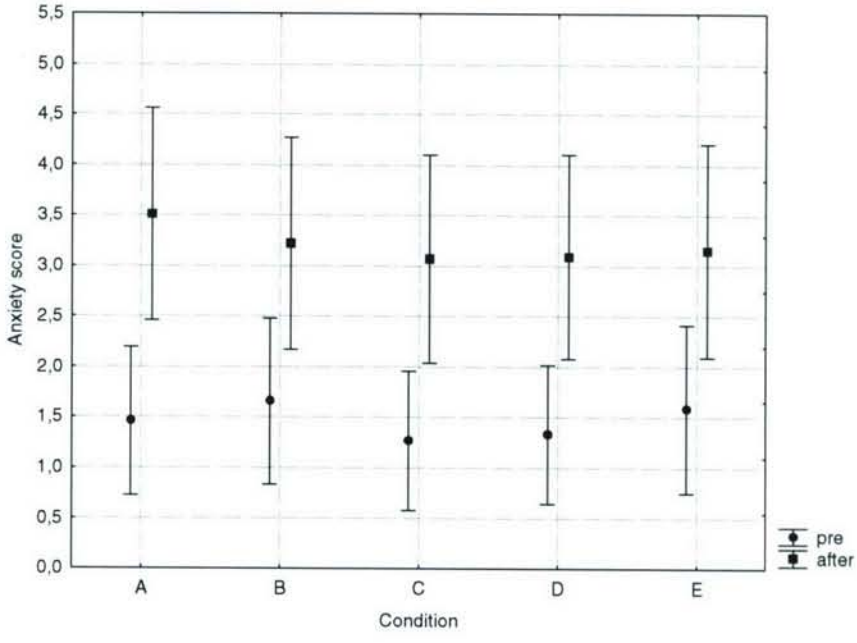

Figure 9 Anxiety scores prior and after the Fire & manoeuvre action for the different protection conditions.

3.2.3 *Physical Exertion*

Prior to the action, no significant differences between protection conditions were found in scores on the RPE scale (Figure 10, Table 9).

Table 9 Physical extertion scores before and after the action.

	Protection condition				
Physical exertion	A	B	C	D	E
Before action	6.3	6.6	6.4	7.1	6.6
±SEM	0.2	0.3	0.2	0.4	0.3
After action	12.1	12.2	11.6	13.1	12.8
±SEM	0.4	0.4	0.4	0.4	0.4

After the action, significant differences were observed between the different protection conditions (Figure 10, Table 9). The RPE score wearing the Simunition suit with

hip belt (condition D) was significantly higher compared with the Simunition suit without hip belt (condition C). Furthermore, a significant difference was found between RPE scores prior to the action (mean score: 6.6) and RPE scores after the action, with the highest scores after the action (mean score: 12.4).

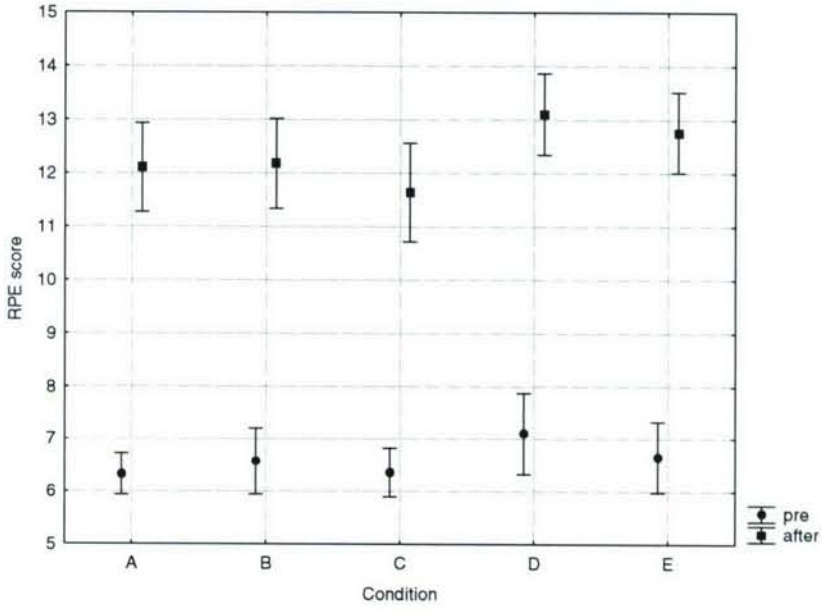

Figure 10 RPE scores prior and after the Fire & manoeuvre action for the different protection conditions.

3.3 Day effects

Almost no significant day effects were found on the measured parameters for the 3 different test days. Only the number of times lying on the ground on the second 30 meter (trajectory B-C) were significantly lower on day 3 compared with day 1. Furthermore, the time to cover the second 30 meter was significantly lower on day 2 and 3 compared with day 1.

3.4 Influence of number of times lying down and time to cover the distance on heart rate.

Both the number of times lying on the ground and the time to cover the distance of the first and second 30 meter had no significant influence on heart rate (mean and max).

4 Discussion

In this study, using a modified version of the study of Koerhuis & Verhagen (2005), the influence of protection, mobility and risk perception on behaviour and physical performance of a combat soldier was assessed.

4.1 Behaviour and physical performance

Before the Fire & Manoeuvre action subjects felt more threatened in the unprotected conditions (condition A and E). Obviously, the combat soldiers were aware of the situation and the benefits of their protection. Prior to the action a negative correlation between the protection level and perceived threat was observed, in compliance with our assumptions. Based on the difference in the perceived threat scores, also differences and a negative correlation in anxiety scores and protection level were expected. However, these differences were not found (prior and after the action). Maybe the pretention of being self-confident can explain these results.

Although the combat soldiers were aware of the situation and the protection condition (different threat scores prior to the action), no significant differences were found in the number of times lying on the ground and the time to cover the distance wearing the different protection conditions. Obviously, despite the higher perceived threat prior to the Fire & Manoeuvre action wearing the unprotected conditions, an almost similar strategy was used to perform the action and the same risk was taken.

Only the low score on perceived threat before the action and the high number of hits on the whole body wearing the ballistic vest indicates a change of behaviour. However, minimal threat was also perceived wearing the Simunition suit with or without hip belt, but did not result in a high number of hits on the whole body. Although no significant differences were found in time to cover the distance, the time to cover the first and second 30 meter was respectively more than 2.5 seconds and 3.9 seconds higher wearing the ballistic vest (condition B) compared with the other conditions. The same results were found if the times of a buddy pair were averaged; more time was necessary to cover the distance wearing the ballistic vest (condition B) for both the first and second 30 meter (more than 3.0 seconds for the first 30 meter and more than 3.6 seconds for the second 30 meter). Obviously, not behaviour differences wearing the different protection conditions, but the time to cover the distance of the action may explain the highest number of hits on the whole body.
Considering the total number of hits on the whole body, the highest number of hits on the unprotected body were found wearing the unprotected conditions. No change in behaviour and less body coverage seems to be a logical explanation for this result.

Because, compared with the study of Koerhuis & Verhagen (2005), the set up of this study resulted in a more equal fight with enough options to hide to cover the distance almost unhurt, an almost similar strategy wearing the different protection conditions was not expected. Also the minimal differences in mean time lying on the ground with (maximal) protection (condition C) and almost unprotected (condition A) were not expected. Because of high level of background noises, combat soldiers sometimes had difficulties to hear each other. It occasionally occurred that a combat soldier shouted to his buddy to run forward, but because of the noise no action was undertaken. The use of communication systems may solve this problem in the future.

Furthermore, it is expected that more alternatives during the Fire & Manoeuvre action (more options to hide over a longer Fire & Manoeuvre distance) may yield a difference in behaviour and physical performance for the different protection conditions.

4.2 Heart rate

In this study, besides the weight of the protection condition, other aspects influenced mean heart rate: based on the weight solely, using a comparable strategy to perform the action, the highest mean heart rates were expected for the higher weight conditions (ballistic vest, the Simunition suit with hip belt and the unprotected condition with hip belt). Although the mean heart rates of these three protection conditions were indeed high, the mean heart rate wearing the Simunition suit without hip belt was similar, despite a lower weight. The mean heart rates wearing the ballistic vest and the unprotected condition with hip belt were even lower compared with the Simunition suit without hip belt. Although not significant, more time was used to cover the distance wearing the ballistic vest, which can explain the lower mean heart rate. With respect to the unprotected condition with hip belt, the similar mean heart rates wearing the simunition suit without hip belt can be caused by an increased body coverage and as a result an increased thermal load, and a lower running efficiency due to the bad fit of the Simunition suit.
Because body coverage, eventually thermal load and risk perception were expected to be the same between the Simunition suit with and without hip belt and the weight of the Simunition suit with hip belt was 8.8 kg heavier than the weight of the Simunition suit without hip belt, the almost similar mean heart rates weraing these two protection conditions were not expected.
Also the maximal heart rate wearing the Simunition suit without hip belt was almost comparable with the maximal heart rate wearing the Simunition with hip belt.
It is expected that both for the mean and maximal heart rate the time to cover the distance was too short to measure significant heart rate differences between the protection conditions. RPE scores corresponded better with our expectations.
A significantly higher score was found wearing the Simunition suit with hip belt compared with the Simunition suit without hip belt. However, the lower RPE score wearing the Simunition suit without hip belt compared with the score wearing the unprotected condition A was not expected. Also here, the time to cover the distance may be too short for a realistic score on perceived exertion wearing different protection conditions.

4.3 Day effects

Day effects were only observed between day 1 and day 3. On day three, the number of times lying down on the ground decreased significantly, resulting in a decrease in time to cover the last 30 meter. It is expected that the minimal number of performed actions on day 3 predominantly contributes to these day effects. Based on observations, it was not expected that these day effects were explained by a change in strategy on day 3 to cover the distance.
Because of the randomly selected (different) protection conditions, no influence of eventually learning effects on the results were expected.

4.4 Unfamiliarity with Simunition

In contradiction to the study of Koerhuis & Verhagen (2005), in this study the subjects were unfamiliar with Simunition. They were therefore not familiar with the pain sensation of a Simunition shot, which increased the perceived threat in comparison with subjects familiar with Simuntion as used during the 2005 experiment.. Because per action on average no more than 2 hits were covered on the unprotected body, no familiarisation with Simunition was realised during the three days experiment.

5 Conclusions

Based on the lessons-learned from the first experiment (Koerhuis & Verhagen, 2005) a modified more realistic fire & manoeuvre action was performed. The significantly higher threat score before the action wearing the unprotected conditions indicated that the combat soldiers were aware of the situation and the amount of protection they weared. During the action an equal fight was observed between subjects and enemies, with both options to fire and to hide. Despite the awareness of the situation and the amount of protection, the subjects did not behave differently wearing the unprotected conditions compared with protected condition.
It is expected that more alternatives during the Fire & Manoeuvre action (more options to hide over a longer Fire & Manoeuvre distance) may yield a difference in behaviour and physical performance for the different protection conditions. With more options to hide, combat soldiers will be forced to make a well-considered choice about strategy to cover the distance, dependent on the protection condition they wear.

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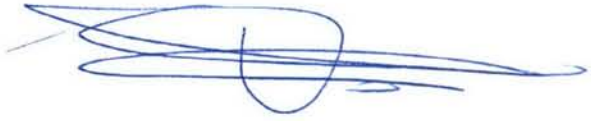
7 Signature

Soesterberg, december 2006

TNO Defence, Security and Safety



C.L. Koerhuis, MSc

Th.L.A. Verhagen, MSc

A Method description and results of the study of Koerhuis & Verhagen (2005)

THE INFLUENCE OF PROTECTION, MOBILITY AND RISK PERCEPTION ON THE BEHAVIOUR AND PHYSICAL PERFORMANCE OF A COMBAT SOLDIER
Preliminary results of the 2005 field experiment

1 DESIGN OF THE EXPERIMENTAL PROGRAMME

The experimental program reflects standard dismounted soldier tasks. The set up of the field study was worked out in close relation with military experts. The experimental programme consisted of three parts: pre-test, followed by a Fire & Manoeuvre action and finalised by a post test. Pre- and post-performance tests were included to quantify the influence of the protection condition (weight, mobility) on specific soldier's tasks. Furthermore, the results were used to quantify the influence of fatigue as a result of the Fire & Manoeuvre action without threat.

1.1 Subjects

Twelve healthy combat soldiers (age: 25.5 years ± 3.7) participated in this study. All were physically highly trained and had no physical complaints prior to the study.

1.2 Simunition

Simunition is used to create a threatening situation. It is expected that the behaviour of the soldier will change in order to avoid the pain sensation (the soldiers' risk perception) which will be inflicted by a simunition hit on the unprotected body. A hit on the *unprotected* subjects' body may result in damage (haemorrhage) on the skin. Simunition was preferred because of the pain sensation in contrast to Simlas, which is comparable with the Miles system.

1.3 Protective Conditions

To simulate the effect of ballistic protection and mobility (weight, protection, surface) attention was paid to the 'protective' conditions. Risk perception was related to the total protected body coverage. As a result, it was decided to define the protective conditions to discriminate between '*no protection – high risk perception*' – '*partial protection – medium risk perception*' – '*total protection – no risk perception*' – in relation to the '*weight-surface distribution*':

- Condition A (combat suit) and B (combat suit with ballistic vest) are in service.
- The simunition suit (condition C and D) offers total protection against simunition impacts. Test subjects are already familiar with these suits in training situations. The protection level of the simunition suit simulates the ultimate ballistic protection dream.
- The (load bearing) belt around the hips (condition D and E) is used to add additional weight to the subject without improving the protection level.

Table 1 Protective conditions

Protective Condition		Weight (kg)	Body Coverage (%)	Protection	Risk perception
A	- combat suit	0	0	unprotected	High
B	- combat suit - ballistic vest	10.9	33.3	partial protected	Medium
C	- combat suit - simunition suit	2.1	75	protected	Low
D	- combat suit - simunition suit - belt around hips	2.1 + 8.8	75	protected	Low
E	- combat suit - belt around hips	0 +10.9	0	unprotected	High

1.4 Pre- and Post test

The pre-test consisted of 4 different tasks; the 'stand up' task was repeated twice (Table 2).

Table 2 The different tasks of the pre- and post test

#	Task	Description
1	Stand up	To stand up from lying position as fast as possible (identical to Task 3)
2	Sprint	16m sprint (flat terrain)
3	Stand-up	To stand up from lying position as fast as possible (identical to Task 1)
4	Reload	To reload the Diemaco weapon
5	Shoot	Shooting performance in standing position, 10m distance

1.5 Fire & Manoeuvre test

In the Fire & Manoeuvre action a threatening situation was simulated. During this action the influence of the protective condition on the behaviour and physical performance was measured.

During the Fire & Manoeuvre action a rural (terrain) distance of ~113 meter was covered in couples. The primary goal was to cover the distance without being hit; the second goal was to cover the distance as fast as possible. The action consisted of three parts (Figure 2, Table 3).

Table 3 Measurements during the Fire & Manoeuvre action

Traject	Distance	Description	Measurement
A-B	~70 m	Fire & Manoeuvre	- Time (s) to cover the distance from A to B - Times lying down on the ground
B-C	~3 m	Weapon reloading	- Time (s) to reload the weapon
C-D	~40 m	'Free action'	- Time (s) to cover the distance from C to D - Description of the action
A-D	~113 m	Total distance	- Number of shots on range targets - Number of hits on range targets - Number of near misers on range targets

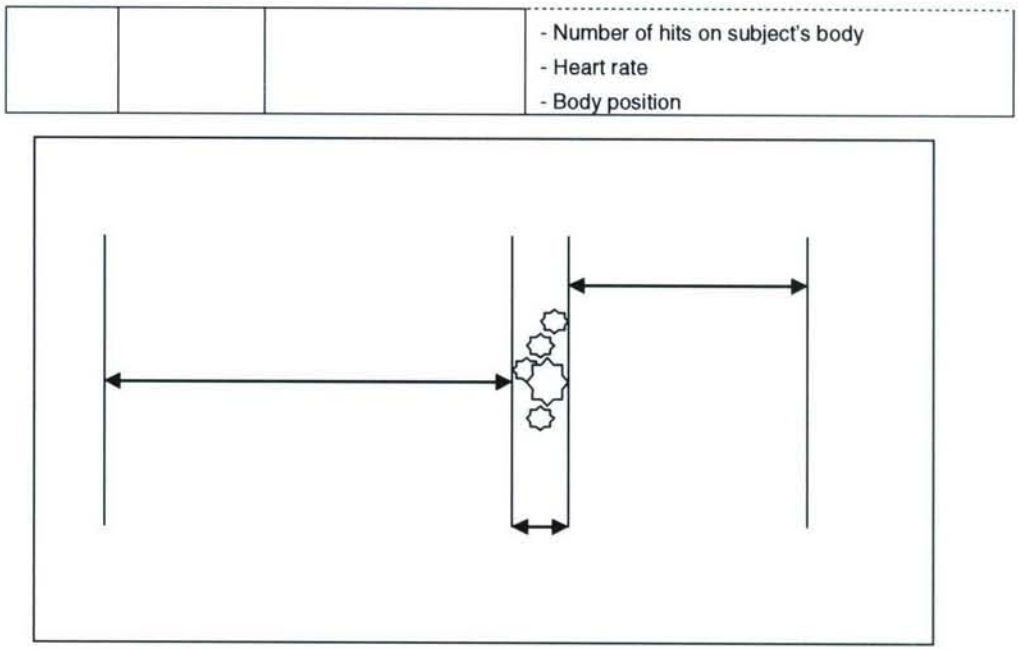


Figure 2 Fire & Manoeuvre action

During the whole action (from A – D, 113 meter), the subjects were fired at with Simunition (single shot mode). The position of the enemies varied continuously. The number of shots an enemy could fire was kept constant for all subjects. The subjects were not allowed to fire at the enemy. The subjects had to fire on rising range targets with the Miles system. The same number of range targets rose per action, with the same duration of 4 seconds for each doll. The sequence of rising differed continuously. Each subject had 30 shots (1 magazine) from A to the reload point (B-C). After reloading were again 30 shots were available per subject for the last part of the action (C-D).

1.6 Subjective rating scales

Before and after the Fire & Manoeuvre action the individual subject score on three subjective rating scales were asked.

Physical exertion scale: For perceived physical exertion a score ranging from 0 (no perceived physical exertion al all) till 20 (extreme physical exertion) was used (Borg, 1982).

Mental scale: For perceived mental exertion a score ranging from 0 (no perceived mental exertion at all) till 20 (extreme perceived mental exertion) was used (Koerhuis et. al. 2006).

Threat scale: For the threat perception during the action a score ranging from 0 (no threat at all) till 20 (extreme threat) was used (Koerhuis et. al. 2006). The score is also dependent on the threat by the subject experienced in the past.

1.7 Experimental protocol

The experiment comprised a sequence of a pre-test, a fire & manoeuvre action and a post test. The time interval between the pre-test and the fire & manoeuvre action

was approximately 5 minutes. The time between fire & manoeuvre action and post-test was about 2 minutes. Before and after the Fire & Manoeuvre action the scores for physical exertion, mental exertion, threat as perceived by the subjects were was asked. During the sequences, the subject couples remained the same.
The experiment was repeated five times, each time with a randomly selected (different) protective condition (Table 1). The time between experiments was 1 hour; it was presumed that the initial subject's physical condition could be regarded as 'physical recovered'.
On the second test day, the protocol of the first test day was repeated.

2 RESULTS

In this chapter a selection of the experimental results is presented. Attention is paid to some of the results of the pre- and post test, the fire & manoeuvre action as well as the scores by the subjects. Furthermore, results of day 1 and day 2 experiments are presented.

2.1 Pre- and post test

Effects of fatigue
Although a reduction in performance during the post-test may indicate fatigue, performance significantly increased in the post-test for some tasks. A significant increase of the velocity to reload the weapon, velocity on the 16m sprint (see Figure 3) was observed during the post test compared with the pre-test. No other significant differences between pre- and post-test were found.

Effect of conditions
The speed to stand from of a lying position, the shooting performance and the weapon reloading were not significantly different between the conditions (see table 1).
The time required for the 16m sprint increased for condition B with 1.4%, for condition D with 8.2% and for condition E with 9.9% with respect to condition A. Hardly any difference was observed between condition A and C (0.07%) (Figure 4).

Conditions B, D and E were compared to determine the effect of body coverage on the 16 meter sprint. The velocity in condition B (ballistic suit) was significantly higher than for condition D (Simunition suit) and E (no coverage) (3.8% and 5.4% respectively) (Figure 4). The effect of weight on the 16 meter sprint performance was analysed by comparing condition C and D (both Simunition suit) and comparing condition A and E (both no coverage). In both comparisons, the conditions with the lowest weight (C and A) resulted in a significantly higher velocity (condition C 7.9% faster than condition D; condition A 9.3% faster than condition E).

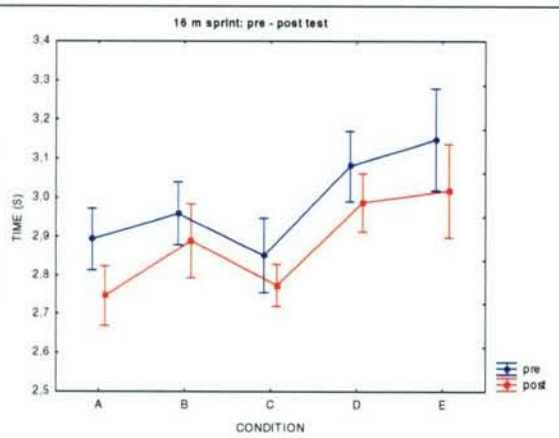


Figure 3 *Time required for the 16 meter sprint during the pre- and post test for the various protective conditions considered (Table 1).*

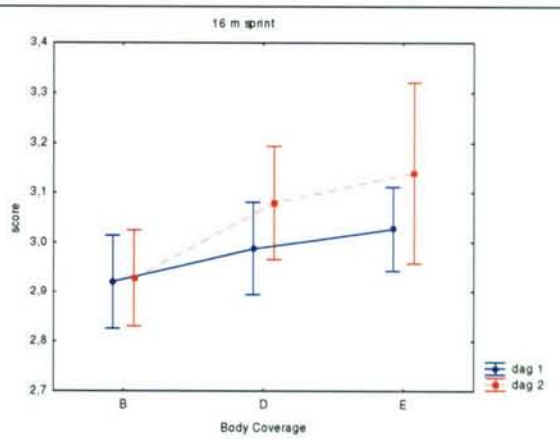


Figure 4 *Effect of body coverage on 16 meter sprint (day 1, day 2).*

2.2 *Fire & Manoeuvre action*

A significant difference between the conditions was found in the time needed for reloading the weapon (Figure 5). The reloading time required for protection condition B (ballistic vest) was significant higher (22.1%) then condition D (combat suit, Simunition suit and load belt).
Relative to condition A (combat suit) a tendency was observed in the time required for the last 40 meter of the test (Figure 6). The time during the last 40 m decreased (higher velocity) in condition B with 21.4%, in condition C with 33.4%, in condition D with 31.4% and in condition E with 31.3% (Figure 6) relative to condition A (combat suit).

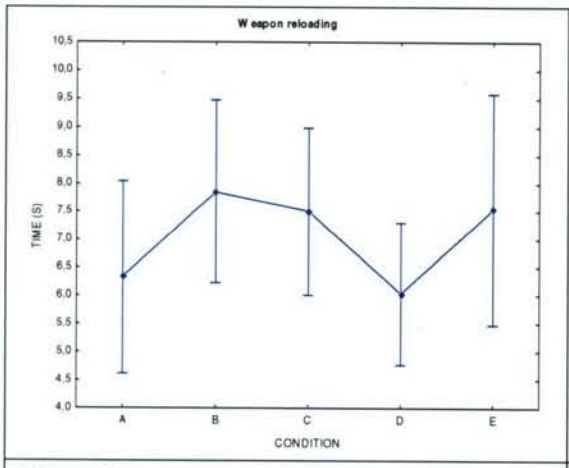


Figure 5 *Reloading time of the weapon for different protective conditions.*

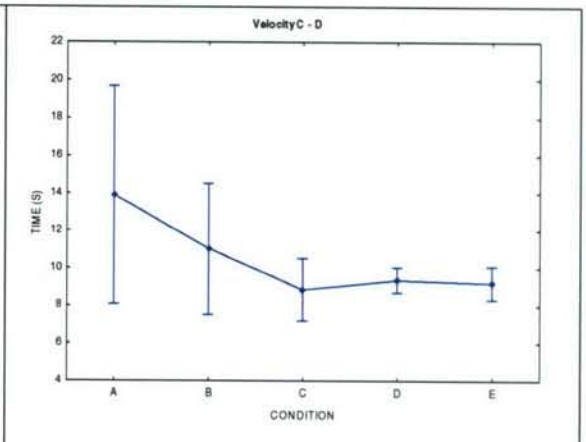


Figure 6 *Time required for the last 40 meter for different protective conditions.*

2.3 *Subjective scales*

Prior to the action, no significant difference between protective conditions was observed in scores for all subjects for physical exertion, mental and threat scale.

However, a significant difference was observed between the subjects' scores prior and after the fire & manoeuvre action. A significantly higher score after the Fire & Manoeuvre action was registered, indicating an increased exertion as perceived. The physical exertion (BORG) scores were significantly higher for protective condition B and D (ballistic vest and simunition suit with load bearing belt) (Figure 7).

A tendency was observed in the scores for the threat scale for the different protective conditions, with the highest scores for the unprotected conditions A and E (Figure 8).

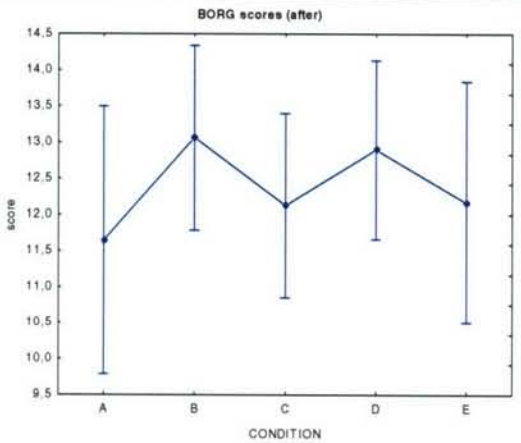


Figure 7 *Scores on the physical exertion (BORG) scale for the different protective conditions after the Fire & Manoeuvre action*

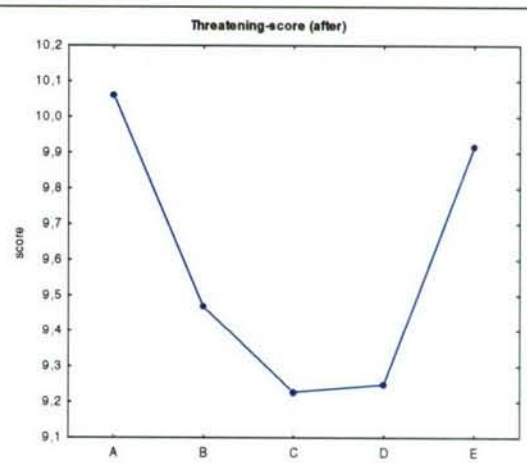


Figure 8 *Scores on the threat scale for the different protective conditions after the Fire & Manoeuvre action.*

2.4 *Day effects*

The experiments were repeated the next day. The sequence of the protective conditions was again randomly determined. Comparing the results of the first and second day a number of interesting observations were made.

For the perceived physical exertion (BORG scale) the scores after the Fire & Manoeuvre action were significantly lower on day 2 than on day 1. For the other subjective scales, no significant day effects were found.

The time necessary to complete Fire & Manoeuvre action improved drastically on day 2 (day 1: 73.4 s, day 2: 56.6s respectively). The velocity for the first 70 meter was significantly higher. This can be explained partly by a significantly lower number of times lying on the ground and standing up (day 1: 3.5 times, day 2: 1.9 times respectively).
During the faster action on day 2, the subjects shot significantly more at rising range targets (day 1: 14 times, day 2: 24.3 times respectively). Of these shots, on day 2 also significantly more hits were observed on rising range targets (day 1: 0.82 hits, day 2: 3.3 hits), resulting in a significant improvement of the shooting performance on day 2.
On the other hand, the number of simunition impacts on the body of the subjects was reduced (day 1: 6.4 impacts; day 2: 4 impacts).

Based upon differences in between day 1 and 2 as well as observations made during the experiments, it can be concluded that on day 2 another strategy was used during the fire & manoeuvre action.

3 DISCUSSION

In this study the influence of protection, mobility and risk perception on behaviour and physical performance of a combat soldier was assessed. Although the influence of protection and mobility on physical performance have been extensively studied in the past (Daanen & Koerhuis, 2003; Holewijn & Lotens, 1987; Ashbey et al., 2004), the influence of threat on behaviour (using Simunition) and as a consequence on physical performance has been added to this study. With the combination of protection, mobility and risk perception, a first step is made to optimally assess the balance between protection and function in a realistic situation.

3.1 Behaviour and physical performance

The subjective ratings (threat scale) indicated that the combat soldiers felt more threatened in the situations without protection (condition A and E). The overall behaviour of the subjects however was in general not significant different during the experiments.
For the threatened situation (Fire & Manoeuvre action), only a tendency was found in the velocity to cover the last distance (40 meter), in which the lowest velocity was found for condition A. Despite that, the highest sprint velocity was measured in condition A during the unthreatened condition (pre- and post test). Strategic reasons can be the cause of the velocity differences in the threatened and unthreatened situation. Maybe for the unprotected condition A of the threatened situation, slalom runs were performed instead of a straight sprint in order to avoid the Simunition shots. Because none of the combat soldiers lied down on the ground during the last 40m, this could not explain the lower velocity in condition A.

Liebermann et al. (2002) studied in exercises, designed to simulate the combat stress, the influence of combat stress on cognitive performance and mood. They concluded that every aspect of cognitive function assessed did severely degrade compared with baseline, pre-stress performance. Relatively simple cognitive functions such as reaction time and vigilance were significantly impaired, as were more complex functions, including memory and logical reasoning. Liebermann et al. (2002) used environmental stress (cold) and psychological stress to study performance as an individual and as part of a small team (Waller, 1994). The presented stress in their study differed from our stress due to Simunition. Based on their study, it was expected that, due to a stressful situation, more time was needed to reload the weapon in the unprotected condition.
However, in our study, the protective condition B (ballistic vest) required most of the time to reload the weapon. Because in the other protective condition D (Simunition suit and load belt) the smallest interval of time was required to reload the weapon, it is expected that in this study, parameters, other than threat, determined the velocity of weapon reloading. Wearing head protection, resulting in a restricted field of vision in front of the subject, and as a consequence restricted eye-hand coordination, may be an explanation for the differences in speed of weapon reloading. Based on the results of the pre- and post test, in which no differences were found in velocity to reload the weapon, weapon reloading could not be influenced by the mobility of the clothing conditions.

Apart from these differences between conditions, no other behaviour and physical performance differences between conditions were observed.

3.2 Heart rate

A remarkable result was that no significant differences in maximal heart rate during the Fire & Manoeuvre action were found for the different protective conditions. Mainly because no significant velocity differences were found between the protective conditions on the first 70 meter of the Fire & Manoeuvre action, differences in heart rate were expected. For condition A, in which the highest sprint velocity in the pre- and post-test was measured, a relatively lower intensity is required to run with the same velocity as in another condition in which the maximal sprint velocity is much lower. Together with the lower velocity in condition A during the last 40 meter of the Fire & Manoeuvre action, the heart rate for condition A was expected to be lower than the other conditions. Despite this, heart rate was not significantly different between the conditions.
Although the frequency of lying down and standing up on the ground could influence the heart rate results, no differences for the number of times lying down on the ground were found.

The similarity in heart rate for the different protective conditions was also in contradiction with the BORG scores in which significantly higher scores were found for condition B (ballistic vest) and D (Simunition suit with load belt).

3.3 Time between experiments

The time between the subsequent protective condition experiments (1 hour) was sufficient to avoid fatigue. Although significant differences existed between pre- and post-test results (16 meter sprint, weapon reloading), the performance level with these tests increased in the post-test.
According to the pre- and post test result, the influence of weight and body coverage could be analysed separately. In accordance with our expectations, the velocity on the 16 meter sprint decreased with increased weight. However, it was not expected that at the same weight level, a partly protected body surface resulted in a higher velocity compared with an unprotected body surface. Maybe the load bearing belt felt more uncomfortable than the ballistic vest with the same weight.

4 LESSONS LEARNED

4.1 Strategy

Based on the threat, it was expected that the unprotected combat soldier (condition A and E) preferred a lying position more often as well as for a longer period than in the protected conditions. This was not found in our study. The reason for this phenomenon was that combat soldiers felt more threatened in a lying position. While lying down, enemies had more time to focus the gun and shoot whenever the combat soldier wants running forward again. Lying down more frequently was only an option if lying down resulted in contact loss of the enemy. Because in our study the enemy was positioned higher (for example on first floors of buildings) than the subject, the enemy could follow the subject everywhere. The constant contact of the enemy with the subject can also explains the increased velocity on day two on the first part (A-B) of the fire & manoeuvre action. After the actions on the first day, the subject knows that lying down on the ground is not a solution for a reduction in hits on the body (independent on the condition). Therefore, the only way to cover the distance from A to B, is as fast as possible with a reduced number of time lying down on the ground. The decrease in hits on the body and the improved shooting performance on day 2 showed that this change of strategy resulted in a better performance.

4.2 Familiarity

Besides the fact that constant contact of the enemy can explain the minimal behaviour and physical performance differences between the conditions, another explanation can be the familiarity of this group of subjects with Simunition. Because this group already trains a lot with Simunition without protective clothing, they were familiar with the effect of Simunition on the unprotected body.
It is expected that the anxiety of suffering from impact (risk perception) is therefore less prominent compared to groups not being familiar with Simunition. More behaviour and physical performance differences are therefore expected by replacing the simunition experienced subjects for inexperienced subjects.

Although in this study a threatening situation was created by using Simunition shots, the subjects advised to introduce a competitive element. Further, constant psychological pressure to perform optimally as an individual, will increase the stress (Waller, 1995), the more so as because the combat soldiers are also trained in this manner.

5 CONCLUSION

It was generally agreed upon that the most realistic experimental simulation of the possibility of being shot at, which is feasible and ethically justified, is related to a pain sensation on unprotected body regions. It is expected that in order to avoid this pain sensation (the soldiers' risk perception) the soldiers' behaviour will change. Notwithstanding the effort and experts opinion involved during the design process only minimal differences in behaviour were observed.

From a critical re-examination of the results found in combination with the set-up of the experimental program it became apparent that the results so far are mainly due to reasons unforeseen during the definition and preparation of the experimental program and/or due to national regulations concerning test persons in combination with simunition. This paper does not pretend to provide all the answers but rather pose questions and put forward some suggestions; amongst others the following points are mentioned:

- The threatening situation during the experiment appeared to be too limited to emphasize the desired effect: The test subjects (special forces) were already familiar with the effect of Simunition. Due to the changed regulations nowadays also soldiers unfamiliar with simunition are allowed to be exposed to simunition.
- The military test persons should be familiar with the military actions included in the experimental program. For the special forces involved in the current experiments, fire & manoeuvre is not included in their daily program.
- The test environment did not offer adequate, realistic coverage opportunities for the test subjects as required for a fire & manoeuvre action.
- Test subjects and the 'enemies' shooting with simunition know each other. As a consequence animosity and/or rivalry between persons and/or groups might in some cases obscure the 'enemy' shooting instructions and divert from the objective of the experiment.

For all parties involved it is evident that experiments are required to increase the understanding and assessment of the influence of protection, mobility and risk perception on behaviour and physical performance of a combat soldier. Based on the lessons-learned from this first experiment it was agreed upon that minor adaptations of the design of the experiment in combination with the selection of the test subjects will improve the overall results considerably. This is subject of the follow-on 2006 experiment (Koerhuis et. al. 2006).

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15. ABSTRACT (MAXIMUM 200 WORDS (1044 BYTE))

In this study, a realistic fire & manoeuvre action was performed to assess the overall effect of ballistic protection, mobility (weight, protection, surface) and risk perception on behaviour and physical performance of the individual combat soldier. Twenty-eight combat soldiers, divided in 14 buddy pairs, participated in this study. The combat soldiers were unfamiliar with Simunition and performed a Fire & manoeuvre action. The significantly higher threat score before the action wearing the unprotected conditions indicated that the combat soldiers were aware of the situation and the amount of protection they weared. During the action an equal fight was observed between subjects and enemies, with both options to fire and to hide. Despite the awareness of the situation and the amount of protection, the subjects did not behave differently wearing the unprotected conditions compared with protected condition. It is expected that more alternatives during the Fire & Manoeuvre action (more options to hide over a longer Fire & Manoeuvre distance) may yield a difference in behaviour and physical performance for the different protection conditions

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